# The Impact of the Issue of Demarcation on Pre-service Teachers' Beliefs on the Nature of Science

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**Abstract**

The arguments about the dimensions of nature of science and the strategies for teaching it are still controversial. In this research, as part of these arguments, a context based on the issue of demarcation of science from pseudoscience was offered and questioned for its effectiveness in nature of science teaching. The research was planned for an educational term and astrology was examined as a case in this context for the criteria proposed by philosophers. A questionnaire composed of open-ended questions which was analyzed qualitatively and used as data source. The results of the research indicated that the context designed was effective in developing the nature of science understandings in various dimensions such as science as an enterprise, experiments, observations, theories, laws, models, scientific methods and the role of socio-cultural values in science.

**Key Words**

The Issue of Demarcation, Nature of Science.

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The development of students' understandings of the nature of science (NOS) has been considered an important aim of science instruction (Kang, Scharmann, & Noh, 2005) and various rationales and practical proposals for teaching the NOS have been offered (Aikenhead, 1997; Bravo, Merce, & Anna, 2001; Matthews 2000). To this end, it is widely accepted that education in science should not only cover the transfer of scientific facts, laws, or theories but also should help individuals understand how scientific knowledge is produced, developed, and change in time, the status of scientific knowledge, the limits of science and the relationship between science and society in order to educate citizens who could contribute to science-related discussions in society and make informed decisions (Bravo, Merce and Anna; Turgut, 2009; Zeidler, Walker, Ackett, & Simmons, 2002). Despite the overall consensus on the necessity of teaching the NOS in school science, there are still two important problems that researchers in the field should overcome (i) lack of consensus between the philosophers of science on some aspects of the NOS (Abd-El-Khalick, Bell, & Lederman 1998; Kang, Scharmann, & Noh, 2005; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Suchting, 1995) and, (ii) developing effective strategies for teaching the NOS.

Despite the discussions at philosophical level, significant academic consensus has been achieved over the years on the aspects of the NOS to be taught in school science (Abd-El-Khalick & Lederman, 2000a; McComas, Clough, & Almazroa, 2000; Ryder, Leach and Driver, 1999; Schwartz, 2009). This consensus underscores the aspects of science such as its (1) tentativeness; (2) empirical nature; (3) theory-laden nature; (4) socio-cultural embeddedness; (4) myth of a universal scientific method; as well as the roles of (5) hypotheses, theories and laws; (6) creativity and imagination; and (7) persuasive communication. This consensus is important for science education and has provided a framework for teaching the NOS (Abd-El-Khalick et al., 1998). With regard to the second problem of the researchers, that is the strategies for the effective teaching of the NOS, two approaches have been dominating the field: implicit (Lawson, 1982) and explicit/reflective approaches (Bell, Lederman, & Abd-El-Khalick, 1998; Lederman, 1998, 2007). Research acknowledges that explicit/reflective approach to teaching the NOS is generally more effective comparing to the implicit approach (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick, & Lederman, 2000; Akindehin, 1988; Bell, Matkins, & McNall, 2002; Haukoos & Penick, 1985; Khishfe & Abd-El Khalick, 2002; Lederman, 1998; Scharmann, Smith, & James, 2002).

What discouraging, however, is that despite the efforts to develop effective teaching strategies, the results of intensive research indicate that students do not possess adequate conceptions of the NOS (Abd-El-Khalick & Lederman, 2000b; Duschl, 1990; Lederman, 1992; Meichtry, 1992). It is considered that the failure in providing meaningful learning contexts that help students' reflect on their beliefs has been the most influential factor in this failure (Castelao, 2002). Therefore, designing effective and meaningful contexts has emerged as the most important barrier for educators in NOS teaching.

To this end, this study aims to assess the effect of a learning context model that has been offered by Turgut (in press) in the development of individuals' understandings of the NOS. At the heart of this model lie the discussions on demarcation of science from pseudoscience. The problem of demarcation — identifying the criteria for differentiating science from nonscience/pseudoscience — has been the central issue of dominant philosophies of science since the early twentieth century and still remains unresolved (Alters, 1997; Anderson, 1983; Bauer, 2002; Dilworth, 2006; Gillies, 1998; Laudan, 1983; Mahner, 2007; Nickles, 2006; Preece, Baxter, 2000). A closer look in to the discussions amongst philosophers of science (such as Kuhn, 1970; Lakatos, 1970, 1981; Laudan, 1983; List, 1982; Popper, 1963) reveals that different philosophers utilized different criteria (logical positivists-observation and verification, Popper-falsification, Lakatos-progressive research programs, Kuhn-paradigms) in their demarcation discussions. However, controversies (as processes) themselves would be more valuable than their conclusions. Thus, philosophical arguments about the nature of reliable knowledge and methodologies to capture it (and thus about science) might be taught and used effectively in NOS education (Hurd, 1998). There are studies indicating that learning and discussion contexts framed on the demarcation of science would be effective and unthreatening learning environments especially for teachers and pre-service teachers who have limited philosophical knowledge regarding science and therefore remain reluctant in discussions involving philosophical bases of science (Turgut, 2009, in press). Using such a perspective, this study aims to assess the effectiveness of a learning context which is framed on science-pseudoscience demarcation and aimed at engaging participants with discussions on aspects of science that demarcate it from pseudoscience.

## Method

A qualitative research approach was utilized in the study. The participants of the study were 38 elementary pre-service science teachers enrolled a 12-week Science-Technology-Society course taught by one of the researchers. As the participants had not taken any course on the nature, philosophy or history of science, the first two weeks of the course program were designed to introduce some basic components of the NOS. The aim of this part of the course was to reveal the misconceptions of the participants regarding the basic aspects of science and engage them with critical reflection on their beliefs. The following six weeks of the course were devoted to the introduction of influential philosophers of science (logical positivists, Popper, Kuhn and Lakatos) and discussions on their criteria for demarcation. During this time, the participants conducted pre-course research on demarcation criteria of philosophers of science each week, involved in classroom discussions, and prepared reports about them in groups. The focus of all classroom discussions during this period was on the aspects of a discipline that makes it more or less scientific (Smith & Sharmann, 1999). Astrology as a case for demarcation was the main theme of the course in the last four weeks and the participants were invited to discuss the status of astrology. In the first week of this period, astrology as a discipline and claims of astrologers were introduced. Then the participants were assigned to prepare a report on the presumptions, methods and knowledge claims of astrology for the next week and a classroom discussion on their findings was conducted. The participants were divided into two opposing groups, one defending astrology as a scientific discipline and the other claiming that it is pseudoscience. Through this co-operative controversy strategy (Hammrich, 1997), the participants engaged in an active reflection on various aspects of the NOS as well as the demarcation of science from pseudoscience.

The impact of the intervention on the participants' beliefs about the NOS was assessed through the Turkish version (Turgut, 2005) of Views of Nature of Science Questionnaire – C form. The form was developed by Abd-El-Khalick (1998) in terms of further modifications on Views of Nature of Science Questionnaire – B which was developed by Abd-El-Khalick et al., (1998). In this development process the form was also examined by a panel of experts in order to increase the validity of the questionnaire (Lederman et al., 2002). The participants filled out the questionnaire before and after the intervention. Data analysis involved reading the responses, generating codes through constant comparison (Bogden & Biklen 2007; Gay, Mills, & Airasian 2006), generating themes and then creating categories using these themes (Creswell, 2005; Maxwell, 2005; Strauss & Corbin 1998). This procedure was applied to both pre- and post course questionnaire data and overall change in participants' beliefs was identified.

## Findings

The analysis of the participants' responses before the course revealed that the majority of the participants possessed naive beliefs regarding many aspects of the NOS. The majority of the participants (84%) viewed scientific knowledge as concrete, absolute and a result of total consensus. In their explanations, they viewed the mission of science as to reach the truth through experiments, whereas they criticize religion and philosophy as lacking concreteness and being subjective. Similarly, the majority of the participants could not define the difference between observation and experiments in science and 79% viewed the role of experiments in science as testing the scientific claims and producing indisputable knowledge. 89% of the participants had misconceptions with regard to the status of scientific laws and theories, the relationship between scientific laws and theories and the tentative nature of scientific knowledge. Generally, these participants viewed scientific theories as predictions or yet to be accepted scientific knowledge which could turn into scientific laws if proven by developing technology and new findings or could be rejected if failed in scientific testing. Although the participants seemed to accept the tentative nature of scientific knowledge, they believed that scientific laws are proven and therefore do not change. Similar to findings in research literature, 79% of the participants believed that there is a universal scientific method that is followed step-by-step by scientists. This belief in the existence of the scientific method made 95% of the participants believe that there is no room for imagination and creativeness in science. Also related to this belief, the majority of the participants (79%) viewed science as objective and universal and denied societal or cultural influences on science.

The responses of the participants to the questions of the VNOS-C questionnaire after the implementation, on the other hand, indicated some positive development in their beliefs about several aspects of the NOS. Notably, the most radical change occurred in participants' descriptions of science. The majority of the participants (79%) used phrases such as "explanation generation", "reasoning", "in search of empirically supported propositions" and "generating tentative conclusions" in their descriptions of science. This transformation in their descriptions of science also affected their approach to experiments and the role of experimentation in science. The majority of the participants (74%) preferred to use "testing" or "falsification" instead of "proving" when talking about experiments in science. Parallel to this belief, the participants also talked of the necessity of empirical evidence in supporting scientific claims. Another dramatic change occurred in participants' beliefs about the status, role and the relationship between scientific laws and theories. A significant number of the participants (76%) described scientific theories as explanations about natural phenomena guiding scientists for a better understanding of nature. Furthermore, only four participants kept their belief in the hierarchical relationship between theories and laws, 68% of the participants, on the other hand, developed more informed ideas about the status and relationship between scientific theories and laws. Also, the participants presented more informed views about the tentativeness of all scientific knowledge, including scientific laws. The implementation process seemed to positively affect the participants' views about scientific method. Closer inspection of the accounts of the participants indicated that 74% of the participants rejected a stepwise universal scientific method. Another development identified was about participants' beliefs about the relationship between science and society and 66% of the participants came to accept that social and cultural factors have an influence on science. In contrast to the above findings, the analysis showed that the majority of the participants (95%) could not developed informed ideas about the role of imagination and creativeness in science. Also a limited development was detected on participants' views on subjectivity in science and only 53% of the participants accepted that scientists' backgrounds, interests and perspectives could affect the course of scientific inquiry.

## Conclusion and Discussion

The analysis of the participants' accounts before and after the implementation indicates that a significant development regarding the participants' beliefs about most of the aspects of the NOS has been achieved through the 12-week course. The development of informed ideas was significant especially on the empirical NOS, the status and relationship between scientific theories and laws, the tentative NOS, the nature of scientific method and the relationship between science and society. Similar development, however, have not been achieved about the beliefs on imagination and creativeness in science. A possible explanation of these results might be the fact that the learning context developed for the study allowed intense discussions on the aspects of science in which the participants' achieved development whereas discussions about the role of imagination and creativity in science did not or rarely discussed during the process. An overall conclusion of this study is that the course design framed on demarcation of science from pseudoscience instead of a traditional NOS course involving broad discussions on all aspects of science could be used effectively in NOS instruction. Such a context engages individuals with basic philosophical problems (Matthews, 1998) and allows them to take part on discussions about the development and status of scientific knowledge (Afonso, Gilbert, 2010; Bartholomew, Osborne, & Ratcliff 2004) in an explicit/reflective manner (Abd-El Khalick, 2005; Bell, 2004; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007). On the other hand, the results also show that the design of the context should be extended in a way to support learning and development for other aspects of science such as imagination and creativeness in science (Khishfe & Abd-El-Khalick, 2002) and the subjective NOS (Akerson et al., 2000).

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